NASA HITCHHIKER PROGRAM

CUSTOMER PAYLOAD REQUIREMENTS (CPR)

HITCHHIKER PROGRAM **STS-XX Hitchhiker**

CUSTOMER PAYLOAD: **Critical Viscosity of Xenon-2**

CUSTOMER: **NASA Glenn Research Center**
for
NASA HQ, Code UG

DATE: **May 21, 1999**

CUSTOMER APPROVAL:		NASA/GSFC APPROVAL:	
Payload Manager	Date	HH Mission Manager	Date
Payload Organization	Date	HH Project Manager	Date

1.0 INTRODUCTION

This document defines the accommodations required for the second flight of the Critical Viscosity of Xenon (CVX-2) experiment on a Hitchhiker (HH) carrier aboard a Shuttle orbiter. The principal contributors are listed in Table 1.

Table 1

CUSTOMER DATA

CUSTOMER PAYLOAD NAME:	**Critical Viscosity of Xenon-2**	
CUSTOMER PAYLOAD ACRONYM:	**CVX-2**	
CUSTOMER NAME, ADDRESS, PHONE:	Susan M. Motil NASA GRC, MS 500-115 Cleveland, OH 44135	(216) 433-8589
CUSTOMER CONTACTS		
PAYLOAD MANAGER:	Susan M. Motil	(216) 433-8589
SYSTEM ENGINEER:	James Myers Dynacs Team 2001 Aerospace Parkway Brook Park, OH 44142	(216) 977-1395
SAFETY:	Sell James NASA GRC, MS 501-4 Cleveland, OH 44135	(216) 433-8618
ELECTRICAL:	Donald Priebe Dynacs Team	(216) 977-1191
SOFTWARE:	Liu Yang Dynacs Team	(216) 977-1037
MECHANICAL/THERMAL:	James Myers Dynacs Team	(216) 977-1395
OPERATIONS:	James Myers Dynacs Team	(216) 977-1445
SCIENCE:	Dr. Robert Berg NIST Gaithersburg, MD 20899	(301) 975-2466
CALENDAR WINDOW REQUESTED:	10/99 to 3/00 for conservative launch	
EARLIEST FHA:	7/21/99	

2.0 PAYLOAD DESCRIPTION

The Critical Viscosity of Xenon-2 (CVX-2) experiment is a basic science experiment designed by a NASA Glenn Research Center project team to implement an experiment proposed by Dr. Robert F. Berg and Dr. Michael Moldover of the National Institute for Science and Technology (NIST). CVX-2 will precisely measure the viscosity and its shear rate dependence of xenon at temperatures very near its liquid-vapor critical temperature (T_c = ~16.7°C). The low-gravity environment of the STS orbiter will minimize stratification in the test sample that inhibits such measurements in normal gravity.

The experiment is proposed to fly in the payload bay on a Hitchhiker (HH) carrier (either bridge or side-mounted). This location is defined primarily by thermal constraints (CVX-2 will be radiatively cooled to slightly subambient temperatures) and by the microgravity environment required (CVX-2 would be less amenable to an active, manned environment).

2.1 MISSION OBJECTIVES

The objective of the experiment is to measure the viscosity of a pure fluid (xenon) near its liquid-vapor critical point. The thermodynamic path will be an approach to the critical temperature, T_c = ~16.7°C, on an isochoric path at the critical density from the one phase (vapor) region. The low gravity environment will enable T_c to be approached 100 times closer in reduced temperature than on Earth before stratification begins to diminish the quality of the measurements.

A continuous scan of temperature will approach and pass the T_c to enable both precise location of T_c and measurement of viscosity at many temperatures around T_c. The primary viscosity data will be acquired during a series of measurements at select viscometer frequencies and amplitudes.

To provide data comparable to the best Earth-based laboratory data, it is required that viscosity be measured with a precision of 0.18% and the viscosity exponent be determined with an accuracy of 1.0%.

2.2 PHYSICAL DESCRIPTION

The CVX-2 flight instrument (Figure 1) is physically separated into two functional units:

1) a CVX-2 Experiment Package (EP) which includes the viscometer and precision temperature control elements and,
2) a CVX-2 Avionics Package (AP) which includes the data acquisition/control electronics and the power conditioning systems.

Table 2a: PAYLOAD ASSEMBLIES

ASSEMBLY NAME	WEIGHT (lb.)	SIZE(in) x y	z	MOUNT TYPE	FOV (deg)	OPERATING TEMP. (°C) Min	Max	NON-OP. TEMP. (°C) Min	Max	STORAGE TEMP. (°C) Min	Max
Avionics Pkg.	130	~19 d	~28	HH	170	25	35	0	45	10	35
Expmt. Pkg.	140	~19 d	~28	HH	170	5	15	0	45	10	35

Each package is mounted in a standard 5 ft^3 Hitchhiker canister and the canisters are connected at the upper endplates by a single, removable, external cable. The payload has provided power and communication support through Hitchhiker standard interface connections on the lower endplate of the Avionics Package. These two packages contain the functional subsystems described below in Sections 2.2.1 and 2.2.2. The two canister configuration is driven by thermal constraints and permits radiative cooling of the primary, science critical elements in the Experiment Package to the required operating temperature by isolating them from those electrical systems dissipating larger amounts of heat. The CVX-2 Upper Endplates are designed by the CVX-2 team and replace GSFC designed Hitchhiker endplates (similar except for hole patterns). This two canister configuration can be accommodated by either Hitchhiker carrier configuration (side mount, -S, or bridge mount, -C).

The instrument will operate on orbit for as long as power is available (a minimum of 200 hours is required) and incorporates command and control capabilities such that the instrument timeline can be optimized to accommodate Shuttle operations or other events which might impact this experiment.

Electrical Design Summary - Electrical systems are distributed within the two canisters as shown in the attached schematic (Figure 2). The functional elements contained within the Experiment Package provide precision temperature measurement and control (to a resolution of a few μK degrees) and precision viscosity measurement. Those functional elements contained within the Avionics (Electronics) Package provide power, communications, and data analysis and recording; a dedicated acceleration measurement system is also contained within this package. For CVX-2, circuitry will be added to permit, selectively, operation at single frequencies and, more importantly, to operate the viscometer with larger voltage offsets which drive the oscillating screen to larger displacements (producing the required higher shear rates).

The CVX-2 power interface is designed to comply with the pertinent requirements of the Hitchhiker Customer Requirements document and established requirements for Shuttle users. Both canisters are always sealed during operation. The subsystems contained in both packages are described in more detail below.

Figure 1: CVX-2 Payload Concept and Selected Details

Figure 2: CVX-2 Electronic Interconnect Flow Chart

Thermal Design Summary - Each canister is radiatively cooled through the uninsulated lid. Both canister lids are equipped with heaters to maintain the desired temperature setpoint during operation. The heaters are active for all but the warmest orbiter attitudes (i.e., Bay-to-Sun). There is no active cooling of the payloads to maintain the temperature setpoints during the Bay-to-Sun attitudes. Thus the experiment can operate for only short periods (< 50 min.) in this flight mode. These heaters have a dedicated analog controller with a programmable setpoint and will control the temperature to better than 0.5 K full swing at a chosen operating point within the accessible range. A standard Hitchhiker configuration, "insulated canisters without upper-insulating end cap", is employed. The insulating blankets (multi-layer insulation with beta-cloth outer shell) and the optical treatment (metallized Teflon tape) for top plate radiators will be provided by GSFC and reflect previously flown materials and designs.

The following table summarizes the predicted temperatures of the CVX-2 assemblies during nominal operation on orbit and acceptable storage temperatures on the ground:

Table 2b: PAYLOAD TEMPERATURE LIMITS

ASSEMBLY/ STATUS	MINIMUM TEMP. (°C)	MAXIMUM TEMP. (°C)	COMMENT
Avionics Package			
Operating	25	35	At Upper Endplate
Non-Operating	0	45	Payload Steady State
Storage	10	35	Payload Steady State
Experiment Package			
Operating	5	15	At Upper Endplate
Non-Operating	0	45	Payload Steady State
Storage	10	35	Payload Steady State

In operation, for extended duration in hot environments, the system may not control at the set point; however, this is a functional concern not a safety concern; there is no hazard associated with loss of environmental control.

The predicted power demands for operating in warm and cool environments are summarized in the following table:

Table 2c: PAYLOAD POWER DEMANDS

THERMOSTATIC EQUIPMENT	DUTY CYCLE (percent by attitude)	POWER (watts)	COMMENTS/DURATION/ ATTITUDE
Lid Heater/EP + thmst. & bridge box	0/21/76	0/20/72	bay to sun/bay to earth/bay to space; 120 W maximum
Lid Heater/AP	0/31/92	0/23/69	ibid.; 187 W maximum
Descent Heater (Thermostat/Shell 2)	0/20/100	0/5/23	ibid.; 23 W maximum Stand-alone, battery powered

The stand-alone descent heater and off-nominal operation of the lid heaters are discussed below in the context of the applicable subsystem.

Structural Design Summary - The primary support structure in both canisters reflects a conservative post and shelf design which has previously been successfully qualified and flown in a Hitchhiker/Shuttle mission. This design provides the structural interface to the Hitchhiker canister at the upper endplate and includes the main load bearing support for the other subsystems. Each structure includes the following components: 2 experiment shelves (5/8 in. thick), 8 shelf mounting brackets, 4 support rails (1 1/8 x 2 in. cross section), 1 mounting plate (3/8 in. thick), and 4 lateral support bumpers. The lateral support bumpers are mounted to the underside edge of the bottom shelf plate and are laterally adjustable with a wedge type assembly. Conservatism of the structure is reflected in stiffness (analysis has shown no natural frequency in either canister to be below 120 Hz) and strength of the structure.

On the basis of CVX-1 analysis per 731-0005-83 Rev. B, "General Fracture Control Plan for Payloads using the Space Transportation System", the primary structures and the individual assemblies of both of the CVX-2 canisters can be classified as *non-fracture critical*. Primary structural components have been shown by analysis to have a factor of safety of at least 2.0 based on yield and 2.6 based on ultimate failure. The payload (within each canister) is well within the maximum payload weight limits (200 lb.) defined for Hitchhiker canisters. There are ***no safety critical elements*** within the payload canisters.

The materials of construction of the CVX-2 payload are chosen from Table 1 of MSFC-SPEC-522B and reflect appropriate stress corrosion properties for the described applications. The primary support structures are fabricated from aluminum (6061-T6) and steel fasteners are employed (300CRES or A286).

Containment analysis **-** A "punch-out" analysis has been performed to demonstrate containment of selected example elements of the payload under worst case free translation conditions. The CVX-1 analysis, which applies to CVX-2, shows that there is substantial margin in this primary containment for ***all elements*** (including rotating elements of fans and disk drive) within both canisters.

2.2.1 Experiment Package (EP)

The Experiment Package (Figure 3a) consists of a CVX-2 Upper Endplate (Figure . 3b; similar to standard HH endplate except for hole patterns) which supports the mounting structure for attachment of selected precision electronics (ratio transformers and related bridge measurement circuitry for μK temperature measurement and control and for precision viscometry measurement) and the thermostat/cell subsystem. The total mass of CVX-2 hardware in the EP is ~144 lb. (including margin). These components fit within a standard 5 ft^3 canister and will be maintained at nominally 15 psi in dry N_2 and will have a canister pressure relief valve set to ~18 psi. The package will be temperature controlled to ~12±1°C (internally) during nominal operation by balancing radiative heat losses with internal lid heaters. Estimated total power dissipated is ~34 W (nominal) or 90 W (peak) for on-orbit operations.

Figure 3a. CVX-2 Experiment Package (cross section)

Figure 3b: CVX-2 Upper Endplate for Experiment Package

The estimated mass data for the Experiment Package are summarized in the following table.

Table 2d. EP MASS ESTIMATES

Assembly	Count	Each (lb.)	Total (lb.)
Support Structure			
Endplate Bracket	1	11.2	11.2
Connector	4	0.51	2.04
Rails	4	3.5	14.0
Shelf	2	18.7	37.4
Shelf Bracket	8	0.41	3.28
Bumper Assembly	4	0.68	2.72
Eurocard Rack	1	20.0	20.0
EMI Filter	1	1.0	1.0
Thermostat Assembly	1	19.0	19.0
Battery Box Assembly	1	20.7	20.7
Estimated Total			131.34
Total + 10% margin			144.47

The calculated center of gravity for this package (based on current weight estimates) is calculated to be:

Table 2e. EP CENTER OF GRAVITY

coord. axis	distance (in.) from canister axis (x, y), upper endplate (z)	HH envelope
x	0.05806	± 2.5
y	0.0	± 2.5
z	-14.7938	-10.4 to -18.8

This is well within the envelope required by the Hitchhiker carrier.

2.2.1.1 Primary Support Structure

As described above, the primary support structure consists of four support posts attached, at one end, to a mounting bracket which attaches to the CVX-2 upper plate and, at the other end, to "bumpers" which are pressed against (but with no hard attachment to) the canister walls during integration. The posts support two shelves in the canister. All electrical and mechanical components mount to the shelves or to the CVX-2 upper endplate. The Experiment Package support rails have a channel configuration which is unique to this package. The total mass of the support structure is 70.64 lb. including fastener hardware.

2.2.1.2 Environmental Control System

The Experiment Package has a dedicated analog proportional controller (card #9 in the Eurocard Rack) and heater to offset heat lost through the CVX-2 upper endplate radiator and to control the canister temperature at an adjustable set point (chosen to be 12 ± 1°C). A thermistor is mechanically attached to the endplate to monitor the temperature. The heater (a pair of adhesively bonded strip heaters) can dissipate a maximum of 75 W at 28 V. Power is drawn directly from the Hitchhiker power line "B"which is protected with a relay. This power is filtered and fused (15 amp fuse down rated to 7.5 amp) before it is applied it to the heater; however, this circuit is switched ONLY by the Hitchhiker relay. During nominal operations (assumed to be bay to Earth) the heater duty cycle is predicted to be only ~7% while in the coldest environment (bay to space) the duty cycle will increase to ~81% or ~61 W power.

CVX-1 analysis (attached as Appendix C) has shown that failure of these heaters "full on" will not lead to hazardous temperatures.

2.2.1.3 Eurocard Rack and Bridge Box

The footprint of this rack is 14.34 by 10.45 in. and the assembled height of the basic rack is ~4.9 in.; the assembly has an estimated weight of 20 lb. The design is a flight hardened version of a standard electronic rack for printed circuit boards of "Eurocard" dimensions. Cooling of this subsystem relies on conductive paths to the upper endplate. Consequently, the electronics contained within this package are limited to those requiring close proximity to the sample cell and those requiring very stable temperature control.

This card rack has 15 slots of which 6 are used for active cards and 6 contain passive heat sinks to improve heat transfer from the interior to the base of the subassembly. This leaves 3 slots unused. The contents of the Eurocard rack are listed in the following table. None of these boards utilize internal batteries of any type.

Table 2f: **EUROCARD RACK CONTENTS**

Slot #	Description	Board Source
1	Lock-in Amplifier Ithaco Model 410	commercial
3	Lock-in Amplifier Ithaco Model 410	commercial
5	Lock-in Amplifier Ithaco Model 410	commercial
7	Telemetry	custom
9	Lid Heater Controller, Bridge Box Heater Contrlr., Relay Driver	custom
12	Inductive Voltage Divider	custom
2,4,6,8,10,14	Heat Shield	
11, 13,15	Unused (13 is inaccessible)	

The Eurocard rack attaches to the upper endplate bracket of the CVX-2 support structure (see Figure 2) and another assembly, the bridge box, attaches to this rack on the side opposite the upper endplate. The bridge box contains a single card which is isolated because it has unique constraints for thermal stability and isolation of the circuits included. The cover for this add-on assembly increases the height of the Eurocard rack by about 1.5 inch giving the combined assemblies a height of approximately 6.5 inches. The box contains a single printed circuit board which includes parts of the precision bridge balancing circuitry used for thermometry and viscometry. The card has independent, low power thermal control for improved stability of these sensitive circuits. Temperature control is provided by a proportional heater control (card #9 of the Eurocard Rack) and a surface heater attached directly to the card.

2.2.1.4 Thermostat

The thermostat assembly is a nested, three-shelled set of aluminum canisters which contain the sample cell. The shells are rigidly mounted by thermally isolating polymeric (Ultem™) spacers and temperature controlled with surface heaters (~10 watt total). The precision control system and thermostat design provides required temperature control at the sample in the temperature range 15° to 40°C. The thermal design employs active control of all three outer shells to achieve the challenging requirements for residual temperature gradient (less than 0.22 µK/cm) and temperature control (to $T \pm 29 \times 10^{-6}$ degrees) near T_c.

The mechanical design permits convenient removal of the cell from the thermostat without complete disassembly. Figure 4 shows the nested shells and spacer configuration. The largest shell is 6 in. in outer diameter and 12.75 in. long. All shells and endplates are 0.25 in. thick 6061 aluminum. The thermostat is supported by an aluminum mount with a polymeric liner that thermally isolates the thermostat from the mounting surface. Each thermostat shell has heaters (near the ends for better gradient characteristics) and thermistors under the heaters for temperature measurement and control. The total mass of the thermostat assembly (including the cell) is 19 lb.

Shell 2 of the thermostat (the shells are numbered from outer to inner with the sample cell being "shell" #4) includes an independent heater and a thermostatic switch for the descent power subsystem (described below).

2.2.1.5 Sample Cell

The sample cell is a small volume (~10 cm^3), moderate pressure (~900 psi) system which is fully contained within the multi-shelled thermostat. The cell contains xenon at precisely its critical density as the working fluid and the working elements of the micro viscometer which is the heart of this experiment. Xenon is a non-toxic, non-corrosive, inert fluid at all pressures and temperatures (note that during the course of this experiment the sample will be either a single phase vapor (above ~16.7°C) or exhibit two phases (liquid and vapor) below ~16.7°C).

Figure 4: CVX-2 Thermostat Cross Section

The cell is designed primarily for thermal characteristics and for the convenience of assembling and filling this delicate subsystem. The design exhibits leak-before-burst protection. It has been determined that this cell rupture is not a credible safety hazard .

The cell has a copper body, one brass endplate with electrical feed throughs, and one sapphire window for observation during the cell fill procedure. Inside the cell, the oscillating screen viscometer element is supported between two pairs of electrodes that provide dual functions: to excite and to detect screen motion. The viscometer mechanism and electrodes are cantilevered from the brass endplate on copper wires. None of these elements have adequate mass to compromise safety and all are immersed in the dense operating fluid. The cell end closures are sealed to the cell body using copper "o"-ring seals clamped with stainless steel screws.

Figure 5 shows a cut away view of the cell assembly. The steel screws provide the "spring loading" which enables the leak-before-burst performance of the design. The total mass of this assembly is approximately 1 lb.

Figure 5: CVX-2 Sample Cell and Viscometer

2.2.1.6 Battery Box (Descent Power Subsystem)

The descent power battery box is located on the lower shelf of the Experiment Package. This stand-alone subsystem is electrically isolated from all other electrical systems and is independently fused and switched. This heat source is a backup system to guarantee that the sample cell (contained within the thermostat) does not drop below the critical temperature for xenon (16.7°C) during re-entry and landing of the Shuttle. This reflects a concern that the viscometer mechanism (a very thin screen supported with wire suspension which is contained within the cell) might be damaged during landing if the sample fluid becomes two-phased (which occurs below the critical temperature) and the liquid phase were to "slosh" against the viscometer mechanism during slap down of the Shuttle. This is ***not*** a safety critical system, but ensures that key measurements can be repeated using the same sample on the ground following the mission.

This subsystem (see Figure 6) consists of a series string of 32 "D" cells, a pair of externally activated relays for redundant control of power to the heaters, a thermostatic switch (hand chosen for the desired operating band), and a strip heater on shell #2 of the thermostat. The circuit is independently fused (a pair of 2 amp fuses each down rated to 1 amp) and electrically isolated from the primary instrument and is designed to maintain the temperature of thermostat shell #2 at ~20°C. This heater is low power (23 Watt at ~0.47 amp and 48 Vdc) and is intended to warm only the interior shell of the thermostat which contains the sample cell. It has been shown by analysis that there is no potential for overheating the payload canister even if the heaters were to fail on.

The circuit complies with JSC-20793 Battery Safety Handbook. No diode is included in the circuit (this element is omitted to enhance reliability and is deemed not necessary due to the simple, series circuit employed). There is no opportunity for back-charging cells in this isolated, serial implementation.

Figure 6: Battery Powered Heater Circuit and Fusing

Alkaline primary cells have been chosen to power this subsystem because they provide simple, low-cost, reliable power for this application. These cells use a "paste" electrolyte within a sealed container (which includes over-pressure relief) and are not prone to leakage when appropriately utilized. Because they are primary cells, they exhibit substantial shelf life (compared to many alternative rechargeable batteries) to minimize concerns for loss of capacity prior to launch.

The batteries, battery mounts, and fuse circuitry are contained within a battery box (Figure 7) which is approximately 14.5 x 9.37 x 3 in. This aluminum box is perforated at the corners to facilitate exchange of atmosphere with the canister and is coated on the interior with an epoxy paint to inhibit corrosion. All connections within the box are conformally coated. The total mass of this subsystem is approximately 20.7 lb.

Figure 7: CVX-2 Battery Box Assembly

2.2.2 Avionics (Electronics) Package (AP)

The Avionics (Electronics) Package (Figure 7) includes power conditioning electronics (total power ~85 W (nominal) or ~187 W (peak)), the data acquisition and control system, and miscellaneous signal conditioning subsystems. A three axis accelerometer is implemented on the center shelf. These components fit within a standard Hitchhiker canister and will be maintained at nominally 15 psi in dry nitrogen.

The digital acquisition and control system consists of multiple processors and support hardware. These include a main processor (running DOS on an STD bus), a card implementing 16-bit A/D, 12-bit A/D, 12-bit D/A, digital I/O. A second processor will provide data reduction in the viscometry system, while a third processor will be used on an independent bus to handle communications and a hard disk for permanent data storage. The communications processor will accept data from the accelerometry processor and the main processor, and must operate as an asynchronous interface to the STS computers. A fourth independent processor logs and analyzes the accelerometer data. None of the processors utilize internal batteries of any type. These electronics are contained within two ruggedized card cages (STD1 and STD2) which are similar in design but differ in functionality of the contents and in location within the package.

The center of gravity for this package (based on current weight estimates summarized below) is calculated to be:

Table 2g: AP CENTER OF GRAVITY

coord. axis	distance (in.) from canister axis (x, y), upper endplate (z)	HH envelope (in.)
x	-0.04143	± 2.5
y	-0.00039	± 2.5
z	-12.7432	-10.4 to -18.8

This is well within the envelope required by the Hitchhiker carrier.

The estimated mass data for the Avionics (Electronics) Package are summarized in the following table.

Table 2h: AP MASS ESTIMATES

Assembly	Count	Each (lb)	Total (lb)
Support Structure			
Endplate Bracket	1	11.2	11.2
Connector	4	0.51	2.04
Rails	4	5.8	23.2
Shelf	2	18.7	37.4
Shelf Bracket	8	0.41	3.28
Bumper Assembly	4	0.68	2.72
STD#1Rack Assembly	1	21.15	21.15
STD#2 Rack Assembly	1	21.15	21.15

EMI Filter	2	1.0	2.0
SAMS Accelerometer Head	1	2.5	2.5
DC-DC Converter	1	1.0	1.0
Estimated Total			127.64
Total + 10% margin			140.40

This package relies primarily on conduction to the top plate radiator for cooling. However, fans (with shrouds) are attached to both card cages to enhance cooling of the electronics.

2.2.2.1 Primary Support Structure

As described above, the primary support structure consists of four support posts attached, at one end, to a mounting bracket which attaches to the CVX-2 upper endplate and, at the other end, to "bumpers" which are pressed against (but with no hard attachment to) the canister walls during integration. The posts support two shelves in the canister. All electrical and mechanical components mount to the shelves or to the endplate. The Avionics Package support rails have a solid cross section (to enhance thermal conductivity) which is unique to this package. The total mass of the support structure is 79.84 lb.

2.2.2.2 Environmental Control System

The Avionics Package has a dedicated analog proportional controller (card #11 in the STD1 Rack) to power three (3) surface mounted film heaters (a total of 112 W) bonded to the interior surface of the upper endplate radiator and to control the canister temperature at an adjustable set point. The package is designed to operate at 32°C while dissipating ~85 W (nominal) to 187 W (peak) of internal power. For nominal attitudes (desirably warm to cold), the canister internal temperature will be controlled to within ±1°C of the desired set point. A thermistor is mechanically attached to the endplate to monitor the temperature. The lid heaters (three (3) adhesively bonded strip heaters) can dissipate a maximum of 112 W at 28 V.

Power is drawn directly from the Hitchhiker power line "B" which is protected with a fuse and switched with a relay. This power is filtered and fused (15 amp fuse down rated to 7.5 amp) before it is applied it to the heater; however, this circuit is switched ONLY by the Hitchhiker relay. During nominal operations (assumed to be bay to Earth) the heater duty cycle is predicted to be only ~7% while in the coldest environment (bay to space) the duty cycle will increase to ~81% or ~91 W power.

Figure 8a: CVX-2 Avionics (Electronics) Package (cross section)

Figure 8b: CVX-2 Upper Endplate for Avionics Package (will be 4" thick and 100 lb mass)

CVX-1 analysis has shown that failure of this heater "full on" will not lead to hazardous temperatures.

Heat exchange is promoted within this package by six muffin fans (three on each card rack) which force air across the electronics, out the base of each rack and against the wall of the canister. The mass of these rotating elements is 1 to 2 oz. and the rotational velocities are less than 3000 rpm making the energy very limited (less than 0.1% of the energy required to puncture the canister) and quite inconsequential in this containment argument. This same argument applies to the 2.5 in. disk drive attached to the STD2 card rack. The CVX-1 analysis verifies that there are no fracture critical elements per TA-94-057.

2.2.2.3 STD1 Card Rack

The STD1 card rack is mounted to the underside of the mounting plate which is attached to the CVX-2 upper endplate bracket on the upper endplate of the Avionics Package canister. The STD1 contains 14 slots which contain the following cards (11 cards and 3 empty slots) on two independent busses:

Table 2i: STD1 RACK CONTENTS

Board #	Description	Board Source
1	Main Processor Winsys LPMSX386	commercial
2	16-bit A/D, Versalogic	commercial
3	1Thermostat Heater FET driver circuit	custom
4	Viscometer Processor Winsys LPM-SX386	commercial
5	16-bit A/D, Versalogic	commercial
6	A/D anti-aliasing LPFs sample and hold	custom
7	Chirp generator circuit (new)	custom
8	Square root circuit (new)	custom
9	Avionics Package and EP lid heater controllers	custom
10	Miscellaneous telemetry	custom
11	Power Amplifier	custom

The card rack is approximately 14.4 in. long x 9.25 in. wide and 8.52 in. high (including the fan pack). The structure is fabricated from 6061-T6 aluminum and the full assembly weighs approximately 21 lb.

2.2.2.4 STD2 Card Rack

The second card rack in the Avionics Package mounts on the lower side of the middle shelf. It utilizes the same card cage as for STD1 with minor modifications to accommodate the hard disk drive which is mounted internally on a rack endplate. This card rack retains the forced air cooling and includes two processors with supporting input/output cards which provide for accelerometry data collection and processing and for communications (up/down link as well as internal exchange of data and commands) and data recording. The following cards are included in the STD2 card rack:

Table 2i: STD2 RACK CONTENTS

Card #	Description	Card Source
1	Communication Processor Winsys LPMSX386	commercial
2	Communications Serial I/O	commercial
3	Accelerometer Processor Winsys LPM-SX386	commercial
4	12-bit A/D Winsys LPM-A/D12M-dc	commercial
5	Accelerometer Filter and ±15V Power Supply	custom
	2.5 in. Hard Disk (340 Mb) shock mounted on rack wall (occupies 1 card slot)	commercial

2.2.2.5 Accelerometer

A triaxial accelerometer head (3 orthogonally mounted Honeywell QA2000 accelerometers) is mounted on the top surface of the middle shelf. This subsystem a source of acceleration data which is processed and used directly by the CVX-2 instrument to identify periods of undesirable background "g-jitter" or major acceleration events. Documenting such data will enable post-mission sorting of viscosity measurements which may have been contaminated by such mechanical activity. The complete subsystem includes this triaxial head and connecting cable plus electronics contained within the STD2 card rack (power supply, analog filter, A/D converter, and a dedicated processor (card #3) to collect and reduce the data and send it to the communications processor for down link and storage). The accelerometer head and attached equipment have a total mass of 2.5 lb.

2.2.2.6 Power Converters/Filters

The power converters (7 commercial units) and primary filters are positioned on the bottom shelf of the Avionics Package.

POWER INPUTS - The CVX-2 instrument will be supplied 28±4 Vdc from the Hitchhiker carrier interface. The power will be drawn from two standard power lines:

1) Hitchhiker power line "B" will power the canister environmental heaters (~7.5 amp maximum), and
2) Hitchhiker power line "A" will power the instrument avionics (~3.5 amp maximum). Line "A" can be independently switched by a CVX-2 relay.

Both circuits are protected with fuses on the Hitchhiker side of the interface and are switched by Hitchhiker avionics. The internal distribution and fusing are shown schematically in Figure 9.

POWER CONVERSION AND DISTRIBUTION - These Hitchhiker power circuits (28 Vdc) enter the CVX-2 Avionics Package where they are filtered, fused (15 amp fuses down rated to 7.5 amp) and conditioned to provide 24 V, 5 V, +/-12 V, +/-48 V and +/-148 V within the Avionics Package. Power at 28 V, 24 V, and 5 V is routed from the Avionics Package to the Experiment Package where an additional power conditioning module produces +/-12 V. Also a high voltage signal (+/- 48 V and +/- 148 V) will be transferred between the Avionics and Experiment Packages, however this signal line will support very low current. Figure 9 shows the fusing, wire sizing and power distribution network. Wires are sized in compliance with the standards set forward in TA92-038.

2.2.2.7 Cables/Connectors

The CVX-2 instrument utilizes a single cable to interconnect the two canisters. This cable attaches to an hermetic feed through on the CVX-2 upper endplate of each canister. This cable will be built per ICD-2-19001 and provide grounded shields at one end only. The cable will be installed by the carrier (GSFC) and is <u>not rigid</u> but is a standard 66 wire flexible design secured by brackets.

Connections to the carrier interface for power (both heater power and electronics power) and for communications (RS-422) occur at the lower endplate of the Avionics Package canister.

2.3 PAYLOAD FUNCTIONAL DESCRIPTION AND METHOD

The primary functions required for the CVX-2 experiment are precise thermal control (to ~24 μK° at the sample), precision AC excitation and low signal-level monitoring of the viscometer, efficient digital control of the instrument for data storage and real-time communication, and commensurate high quality power and signal conditioning. Active temperature control is provided at multiple levels but is ultimately dependent upon

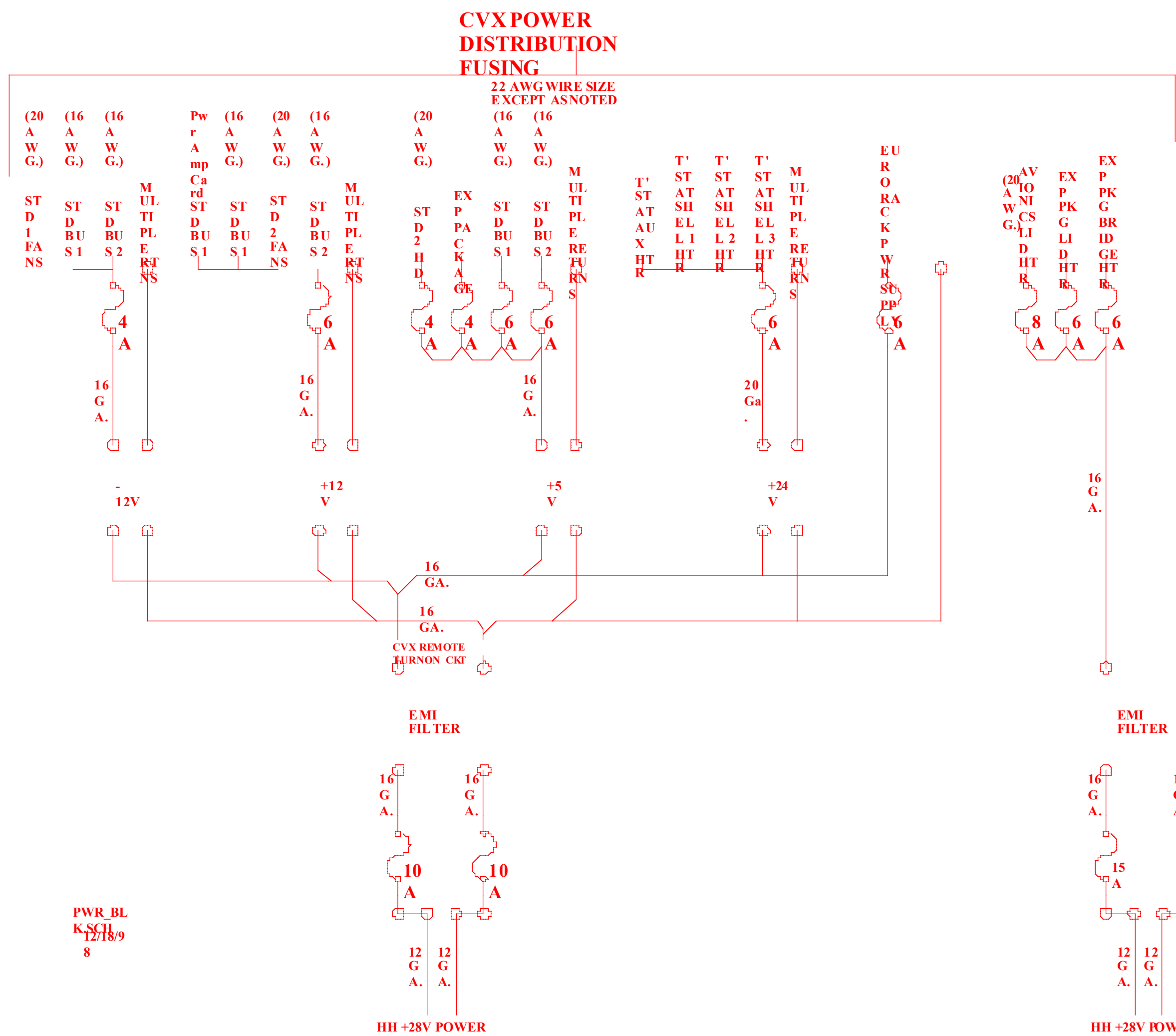


Figure 9: CVX-2 Power Distribution and Fusing

radiative heat loss from the canister. The thermostat employs three independent bridge circuits (2 DC and one AC bridge circuits) to control the outer shells of the thermostat at carefully chosen temperature offsets from the desired sample temperature and the EP canister is controlled about a chosen set point (~10°C).

Viscosity measurements are made using a very light weight metal screen as a forced oscillator (in a "see-saw" motion about a single suspension wire) and quantitatively measuring the drag at each sample temperature. The screen is electrically excited and its position is monitored capacitively. The complete electromechanical mechanism is sealed within the sample cell.

Digital control and communication are provided with multiple processors and a software system providing for either autonomous operation or interactive reset capabilities. All data will be stored on a magnetic hard-disk drive and selectively transmitted to the ground. Local accelerations are monitored, processed, and sent to the communications processor to be stored and downlinked.

High quality power and communication requirements are fulfilled using conventional electronic systems implemented with substantial care to minimize part per million level noise which could interfere with the precise temperature and viscosity measurements.

2.4 OPERATIONAL SCENARIO

The CVX-2 experiment is expected to be powered as early as possible on orbit and will be operated for as long as possible during the mission. Once the instrument is thermally stable, a fast temperature scan will be performed to locate the critical temperature and to permit precision measurements of viscosity in the vicinity (within a few millionths of a degree) of the critical temperature. The most important scan is very slow and requires several days of continuous operation. The overall operations concept is further discussed below. While the instrument can operate autonomously, the more desirable mode requires interaction to monitor data and experiment progress and to selectively command the instrument to accommodate unpredicted trends in the data or orbital events which might perturb the measurements.

2.4.1 OPERATIONS DESCRIPTION

Experiment Sequence - The primary sequence of experiment operations is shown below in Figure 10. The first action of the experiment will be to establish the location of T_c within 0.3 mK. A series of viscosity measurements during a fast temperature ramp starting at 0.1K above T_c. This temperature ramp should take about 24 hours. This operation will validate the viscometer response as compared to CVX-1 results. The primary viscosity data will be acquired during a series of measurements at a single viscometer operating frequency and four different viscometer amplitudes at each of 10 temperatures logarithmically distributed from 0.3 mK to 3 mK above T_c. A third data set will repeat the measurements at two significantly different viscometer frequencies.

During the turn-on sequence, CVX-2 power is activiated (verbal command by CVX-2; bilevel command by GSFC) and the lid heaters are powered on. CVX-2 Avionics power is commanded off (as a precaution - it should already be off) by GSFC via bilevel command lines until the internal temperature reaches 10 C, at which point the avionics power is commanded on, again by GSFC.

During shut down operations the CVX-2 Avionics will be powered off first via GSFC bilevel commands. Then, as late as possible, CVX-2 lid heaters will be turned off when CVX-2 instrument power is switched off by GSFC. If landing delays occur, CVX-2 will request that instrument power be kept "on" (or reactivated) to maintain temperatures above T_c without relying solely upon the battery supplied heater.

Figure 10: CVX-2 Flight Experiment Sequence

INITIALIZE -------->	HEAT UP	-------------> 3 Cycles <-------------	RAMP TO Tc --------------->	SHUT DOWN
2 Stage Turn-on Lid Heaters On Monitor Temp Electronics On Initialize Boards System Check	Energize Heaters Check for Start Temp Check Error Flags Read/Log Temperatures Read/Log Health Data		Control Temperature Set Viscometer Frequency/Amplitude Read/Log Viscometry Data Read/Log Temperatures Read/Log Health Data Read/Log Accelerometer Data Check Error Flags Temp Bridge Gain Settings Process Uplink Commands Downlink Data	Increase Temperature Activate Descent Heater Relay Deactivate

Science Operations Summary - The ability to operate the CVX-2 experiment properly will be influenced by the temperature of its Hitchhiker canister, by the Shuttle's vibrations, and by the communications to ground.

The heart of the experiment is the small sample of xenon. As with other critical point experiments, its average temperature will be controlled very carefully, to within 30 μK. In addition, temperature differences within the sample will be kept to less than 0.1μK/cm. Both of these requirements will be met by CVX-2, provided the Hitchhiker's external temperature remains within the bounds assumed. However, an unexpected and extreme temperature disturbance could cause the loss of as much as 3 days of data. This sensitivity to temperature disturbances is due to the very slow equilibration characteristic of fluids near the critical point.

Within the xenon, a delicate oscillator will measure the viscous resistance. This measurement can be disturbed by excessive Shuttle vibrations. The oscillator will be operated continuously, and excessive mechanical disturbances can be tolerated if they are merely occasional, say less than 5 minutes per hour.

The experiment calls for slow variation of the sample's temperature. Thus, although communication with CVX-2 will be essential, an occasional lack of communication will be tolerable.

In the timeline that follows (Table 3), the data taken within 100 mK of T_c is the most critical. This corresponds to the temperature range where accurate data cannot be obtained on earth because of limitations due to gravity. The graphical representation of the timeline is shown in Figure 11.

This timeline includes a conservative scenario for start-up (slow for both HH and CVX-2). We note that complications delaying start-up of HH (a delay making CVX-2 too cold) would likely slow the thermal start-up for CVX-2.

Table 3: CVX-2 TIMELINE

Sequence	Event	Event Time	Total Run Time
1.	Cool Down (Cool to T_c + 0.1 K)	22.5 hr	22.5 hr
2.	Pass 1 (Locate T_c to within 0.1mK)	36.6 hr	59.1 hr
	a. Calibrate chirp and observe .5 Hz	13.2 hr	
	b. Step to T_c + 0.05 K	4.0 hr	
	c. Ramp to T_c – 0.02 K (S9)	19.4 hr	
3.	Pass 2 (Shear thinning at 1 frequency)	64.8 hr	123.9 hr
	a. Equilibration measurement	7 hr	
	b. 1 Frequency at 4 amplitudes (S6)	12.3 hr	
	c. Ramp to T_c + 0.003 K	13.1 hr	
	d. Ramp to T_c + 0.0 K (assumes T_c is known to 0.1mK)	33.3 hr	
4.	Pass 3 (Shear thinning at multiple frequencies)	64.8 hr	188.7 hr
	a. Equilibration measurement	7 hr	
	b. 4 frequencies at 3 amplitudes, then 0.5 Hz (S7)	12.3 hr	
	c. Ramp to T_c + 0.003 K	13.1 hr	
	d. Ramp to T_c + 0.0 K (assumes T_c is known to 0.1mK)	33.3 hr	
5.	Warm Up (Warm cell far above T_c to prepare for landing, S10)	10.0 hr	198.7 hr
			(8 d: 6.7 h)

2.4.2 CRITICAL PROCEDURES

The only procedure that can place the CVX-2 instrument health in jeopardy is the initial turn-on procedure. If the sample cell is allowed to drop below 0°C, then it may leak (the cell has a narrow range of working temperatures, nominally 0° - to 45°C). Due to the nature of the seals, materials of construction, and the required precision of the fill; thermal expansion mismatch can increase the leak rate when this tested range is exceeded.

Analysis has shown that instrument temperatures below 0°C may be reached if CVX-2 power is not applied within 24 hours of launch. Also, if delays occur in reaching thermal equilibrium in order to start the experiment, significant loss of experiment time may occur, placing subsequent operations in jeopardy.

Similarly, any subsequent operation after initial turn-on (such as a Shuttle maneuver to a very warm attitude) that places the thermal environment in jeopardy will evoke CVX-2 concerns. Section 4.3 of this document addresses the thermal constraints for CVX-2 operations.

Subsequent to the initial scan through T_c, the as-observed on orbit value for T_c will be transmitted to the flight instrument as the reference for the remaining experiments. It is important to reference subsequent measurements to this on-orbit measurement and a command window to transmit this key data will have high priority.

A very critical procedure occurs during the temperature scan for the "primary viscosity data set". Excessive background acceleration could also jeopardize this critical operation. It is believed that the instrument can continue useful operation through all expected Shuttle operations; however, selected inhibits will be requested for major Shuttle operations which could seriously perturb the thermal or acceleration environment. Loss of thermal control or extended periods (many tens of minutes) of vibration could produce significant loss of data with no opportunity to recover. The detail of such constraints is discussed in detail below (Section 4.).

3.0 PAYLOAD REQUIREMENTS FOR CARRIER STANDARD SERVICES

3.1 CARRIER TO PAYLOAD ELECTRICAL INTERFACES

The payload will meet the standard electrical interface requirements (including connectors, pin assignments, impedance, signal levels, etc.), specified in the CARS. This payload will require 1 standard signal interface connection or "port", 1 standard power interface connection or "port" (understood to include two 10A power lines and 1 2.5A auxiliary heater line), and 4 bilevel command lines. The 2.5A power line is not planned for use. The standard HH electrical services required by CVX-2 are listed in Table 3.1. Unused services will be left open circuited in the payload unless other termination is required by GSFC.

3.2 CARRIER TO PAYLOAD MECHANICAL INTERFACES

The CVX-2 instrument will meet the standard mechanical interface requirements specification in the CARS. Mechanical drawings and other documentation will be supplied in sufficient detail for GSFC to perform user accommodation studies and ultimately draft the MICD. Section 2 of the CARS addresses most of the information required for accommodation studies. The MICD Requirement Information List in Section 3.1.1.3.2 of the CARS lists data required for inclusion on the MICD.

TABLE 3.1: STANDARD AVIONICS PORT REQUIREMENTS

STANDARD ELECTRICAL INTERFACES:	1
SIGNAL INTERFACE DETAILS:	
NUMBER OF BILEVEL COMMANDS:	4 lines
NUMBER OF THERMISTORS/PRESSURE:	2 thermistors and 1pressure sensor for CVX-2 Avionics Pkg.
ASYNCHRONOUS UPLINK:	yes
ASYNCHRONOUS DOWNLINK:	yes
MEDIUM RATE KU-BAND DATA RATE:	no
ANALOG DATA:	no
IRIG-B GMT:	no
GMT MIN:	no
CREW PANEL SWITCHES:	no
ORBITER CCTV INTERFACE:	no
PORT TO PORT INTERCONNECT REQUIRED:	no
POWER INTERFACE CONNECTION	
POWER CIRCUIT A (amps max):	3.75 amps
POWER CIRCUIT B (amps max):	6.5 amps
TOTAL ENERGY REQUIRED (A&B):	~24 kWhr (10 day incl. heater)
(bay-to-earth attitude)	~20 kWhr (10 day electr. only)

OTHER: (1) CVX-2 requires **current sensors** on both A & B power circuits
(2) **Bilevel commanding** (4 lines) controlled by HH cadre (upon CVX-2 request)
(3) CVX-2 requires frequent **replay of LOS data** from STS Ops Recorder

The CVX-2 instrument will mount in two standard 5 ft^3 HH canisters which are expected to be side-by-side. Standard mechanical mounts will be sufficient. Brackets to support the canister interconnecting cable are to be supplied by GSFC. The custom top plates and interconnecting cable will be provided by the CVX-2 team and submitted for HH approval.

The estimated mass data for the CVX-2 instrument (no canister hardware) are summarized in the following tables:

Experiment Package Mass Data

Assembly	Count	Each (lb.)	Total (lb.)
Support Structure			
End Plate Bracket	1	11.2	11.2
Connector	4	0.51	2.04
Rails	4	3.5	14.0
Shelf	2	18.7	37.4
Shelf Bracket	8	0.41	3.28
Bumper Assembly	4	0.68	2.72

Eurocard Rack	1	20.0	20.0
EMI Filter	1	1.0	1.0
Thermostat Assembly	1	19.0	19.0
Battery Box Assembly	1	20.7	20.7
Estimated Total			131.34
Total + 10% margin			144.47

CVX-2 Avionics Package Mass Data

Assembly	Count	Each (lb)	Total (lb)
Support Structure			
End Plate Bracket	1	11.2	11.2
Connector	4	0.51	2.04
Rails	4	5.8	23.2
Shelf	2	18.7	37.4
Shelf Bracket	8	0.41	3.28
Bumper Assembly	4	0.68	2.72
STD#1Rack Assembly	1	21.15	21.15
STD#2 Rack Assembly	1	21.15	21.15
EMI Filter	2	1.0	2.0
SAMS Accelerometer Head	1	2.5	2.5
DC-DC Converter	1	1.0	1.0
Estimated Total			127.64
Total + 10% margin			140.40

3.3 CARRIER TO PAYLOAD THERMAL INTERFACES

The CVX-2 payload will meet the standard thermal interface requirements specified in Section 2.2 of the CARS.

The thermal design of the CVX-2 instrument relies upon:

a) thermal isolation from the primary support structure as provided by the standard HH mounting adapters;
b) radiative cooling from the canister top plates offset by surface heaters actively controlled around an adjustable set point; with
c) thermal insulation of canister walls by standard HH multilayer insulation blankets.

The acceptable envelope of orbiter attitudes which permit CVX-2 operations will be constrained from very warm (bay-to-sun) attitudes. See Section 4.3 of this document.

3.4 GROUND OPERATIONS REQUIREMENTS

Eight phases of ground operations are envisioned for CVX-2:

1) Shipment to GSFC;
2) Off-line operations at GSFC to unpack, assemble and check-out instrument prior to turn-over to HH;
3) On-line operations at GSFC for integration, test, and interface verification by HH at GSFC;
4) Shipment to KSC;
5) On-line operations at KSC for integration, and interface verification.
6) Mission operations (POCC) at GSFC *and/or at GRC User Operations Facility*;
7) De-integration of CVX-2 from HH at KSC
8) Shipment to GRC.

Shipping operations 1, 4 and 8 will be by truck. Operations 1 and 8 will be controlled by CVX-2 and operation 4 by GSFC. Primary CVX-2 constraints demand visibly clean cleanliness standards to protect the instrument, and temperature control to guarantee that the instrument temperature (in particular, the sample temperature) does not go below 17°C while the instrument is in motion. Below 17°C, the sample will become two-phased (vapor and liquid) and sloshing liquid could damage the viscometer mechanism if moderately aggressive impacts occur. Maximum acceptable temperature is 35 °C. CVX-2 will require GSFC support for all lifting operations (fork lifts for removal from truck and transporting crates to work area; certified slings and cranes to remove payload elements from crates and assemble for test or integration). Standard (certified) eyebolts will installed into the CVX-2 upper end plates as lifting fixtures.

Operation 2 covers the final check-out of the instrument prior to turn-over to HH for integration. Checkout operations will be fully conducted by the CVX-2 team. It requires a visibly clean laboratory environment and standard laboratory services (accessible 110 Vac outlets for ground support equipment) to accommodate the equipment listed in Table 4.

Operations 3 and 5 will invoke CVX-2 procedures but will be controlled by HH and/or KSC personnel. CVX-2 requirements focus on verification of all functional and interface capabilities. Access to connect a GSE terminal for command and functional check-out is the primary requirement. Operation 3 includes installation of radiator tape by GSFC.

Operation 6 provides for around the clock interactive operation of the instrument by the CVX-2 team in the GSFC controlled environment of the POCC.

Table 4: GROUND OPERATIONS REQUIREMENTS

a.	MAXIMUM AND MINIMUM ALLOWED STORAGE TEMPERATURES:	35°C Max. (sample cell) 10°C Min. (sample cell)
b.	MAXIMUM AND MINIMUM ALLOWED RELATIVE HUMIDITY:	10-80%
c.	CLEANLINESS REQUIREMENT FOR PAYLOAD INTEGRATION & TESTING:	visibly clean
d.	CUSTOMER SUPPLIED GSE REQUIRED	see k below
e.	REQUIREMENTS FOR GASES AND LIQUIDS:	dry N_2 for canisters; GSFC purge, seal, and leak check

f. REQUIREMENTS FOR PAYLOAD SERVICING AT GSFC: support for all lifting operations; integration, functional test, and interface verification

" " " " " KSC: functional test/interface verification

g. REQUIREMENTS FOR ACCESS DURING ORBITER INTEGRATION: none

h. REQUIREMENTS FOR ACCESS ON LAUNCH PAD: none

i. REQUIREMENTS FOR POST-LANDING ACCESS: none

j. ANY OTHER SPECIAL REQUIREMENTS FOR HANDLING: Maintain >17°C during shipment and handling

k. SIZES AND WEIGHTS OF ITEMS REQUIRED FOR SHIPMENT TO INTEGRATION OR LAUNCH SITES:

Off-line Check-out at GSFC:

ITEM	~Crate Size (ft)	~Weight (lb)
1. Electrical test equipment	2 x 3 x 4	150
2. PC and printer	2 x 2 x 4	100
3. Assembly cart for AP	1.5 x 2.5 x 4	100
4. Assembly cart for EP	1.5 x 2.5 x 4	100
5. Cables, supplies, tools, misc.	2 x 3 x 4	150
6. Payload Assembly (AP)	2.5 x 2.5 x 3.5	200
7. Payload Assembly (EP)	2.5 x 2.5 x 3.5	200

On-line Functional Test at GSFC and KSC

ITEM	~Crate Size (ft)	~Weight (lb)
1. Electrical test equipment *(if rqd.)*	2 x 3 x 4	150
2. PC and printer (1 ea.)	2 x 2 x 4	100

Mission Operations at GSFC:

ITEM	~Crate Size (ft)	~Weight (lb)
1. PCs, monitors, keyboards (2 ea.)	2 x 3 x 4	150
2. PCs, monitors, keyboards (2 ea.)	2 x 3 x 4	150
3 Printers (2 ea.), documentation	2 x 3 x 4	150
4. Cables, supplies, tools, misc.	2 x 3 x 4	150

3.5 SAFETY

Table 5 identifies payload safety items in the requested format. Details are given below.

The pressurized sample cell is presented as a non-credible hazard. It is fully contained, has the leak-before burst feature, does not significantly affect internal canister pressure if fully vented, and contains a non-toxic, non-flammable, non-corrosive gas. There are precedents within recent JSC Safety Panel experience for treating similar devices as non-credible hazards in the payload bay and hand-held in the mid-deck.

TABLE 5: PAYLOAD SAFETY RELATED ITEMS

a. CONTAINS PRESSURIZED VOLUME:	yes

b.	CONTAINS RADIOACTIVE MATERIAL:	no
c.	CONTAINS LIGHT OR RF SOURCE:	no
d.	EXTERNAL ELECTRIC OR MAGNETIC FIELDS:	yes
e.	EXTERNAL ELECTRICALLY CHARGED SURFACE:	no
f.	EXTERNAL HOT OR SHARP SURFACE:	no*
g.	CONTAINS TOXIC MATERIAL:	no
h.	CONTAINS OUTGASSING MATERIAL:	no
i.	VENTS FLUIDS OR GASES:	no
j.	CONTAINS CRYOGEN:	no
k.	HAS MOVING EXTERNAL PARTS:	no
l.	CONTAINS EXPLOSIVE DEVICES:	no
m.	CONTAINS OR GENERATES EXPLOSIVE OR FLAMMABLE MATERIAL/GAS:	no
n.	CUSTOMER SUPPLIED GSE CONTAINS RADIOACTIVE MATERIAL, LIGHT OR RF SOURCES, PRESSURIZED VOLUME:	no
o.	ANY OTHER HAZARD:	yes

DESCRIPTION OF IDENTIFIED HAZARDS:

a. ~10 cc of xenon at ~58 atm. (~900 psi) in a sealed sample cell. This is not considered to be a credible hazard due to "leak before burst" design of cell and multi- shell containment provided by the surrounding thermostat and canister.

d. Conventional electrical/electronic devices are included within the instrument; this YES assumes typical, acceptable levels of EMI

f. * Surface heaters could reach ~35°C in nominal operation or ~74°C in worst case (5 heaters simultaneously failed "on").

o. Experiment Package contains batteries (32 "D" cell in an isolated and fused series string.

3.5.1 SAFETY MATRIX

Payload Safety Requirements Applicability Matrix, Payload Safety Requirements Applicability Descriptive Data sheet, and Payload Ground Safety Requirements Applicability Matrix are included below. These are consistent with the Flight Safety Package submitted 5/1/95.

4.0 MISSION OPERATIONS REQUIREMENTS

The CVX-2 experiment will operate for the duration of the mission. The experiment requires a minimum of ~200 hours of operation to attain the desired data set and can repeat or extend selected measurements to gain useful data during any additional time available. The two phase start-up of the instrument requires CVX-2 interaction with the HH Operations Manager to determine the appropriate time (and temperature) at which the electronics are powered.

The experiment can perform autonomously, if required, but the most desirable scenario includes interactive control. Commanding will utilize a small set of predefined commands which will provide the ability to pause, adjust parameters, and restart the experiment.

The experiment requires very precise temperature control (to a few millionths of a degree) and will be radiatively cooled. This makes the instrument susceptible to Shuttle attitudes which produce extremes (hot or cold) in the thermal environment. Loss of thermal control at the sample would require significant delays to re-equilibrate and restart the experiment. The CVX-2 team will attempt to accommodate such attitudes, if they occur.

This is a "microgravity experiment" with a sensitive, precision hydro-mechanical sensor for measuring viscosity. The experiment can be adversely affected by excessive background accelerations resulting from Shuttle operations or vibrations. Accelerations greater than 10^{-4} g in a frequency range of ~1 to 10 Hz are considered "excessive".

The CVX-2 position on the required environment (as relayed to JSC in the 2/14/96 telecon) is summarized here and detailed in Sections 4.3 (Thermal Constraints) and 4.9 (Contamination Constraints):

> The thermal or acceleration environment can affect the CVX-2 measurement system (a temporary effect) or the sample (requires starting over and, possibly, a fatal effect). Where you see question marks we will try to calculate the DC acceleration threshold for that distance from T_c, since the sample is less sensitive farther from T_c. This is not an easy task, and until then we have to work with the close to T_c constraint. Time is given as hours from CVX-2 turn-on.
>
> If we cannot schedule events (maneuvers and bay-to-sun) around the CVX-2 timeline, we can try to shift the CVX-2 timeline. However, CVX-2 will be getting closer to T_c as the primary data scan progresses. If unexpected events occur during the mission, the best that could be done is to slow the ramp or perhaps even pause it. This does not prevent the sample from being sensitive; it can only prevent it from becoming more sensitive.
>
> i.e., AC accelerations are not a big concern. DC accelerations are the largest concern followed by bay-to-sun attitudes (assuming use of the 100 lb lid).

4.1 OPERATIONAL SCENARIO

At power-on, experiment power will activate the environmental control heaters and the bilevel command for CVX-2 Avionics off will be sent by GSFC. Both canisters will be allowed time to reach the desired turn-on temperatures (~10°C for EP, and AP). The time required depends on temperature at launch, shuttle attitude, and time to power-on and could require several hours. When the canisters achieve operating temperatures (temperatures will be monitored via HH telemetry lines), the CVX-2 Avionics will be powered-on via a bilevel command and experimental operations initiated.

The first action of the experiment will be to establish the location of T_c within 0.1 K. This will be accomplished with a series of viscosity measurements during a fast temperature scan starting at ~7 K above T_c (as established by ground calibration) and continuing below T_c . This temperature ramp will require about 22 hours. High voltages will not be run in the first 24 hours of the experiment.

The primary viscosity data set will be acquired during a second temperature ramp starting at 0.1 K above T_c and locating T_c within 0.1 mK. During this time, the chirp will be calibrated, and the 0.5 Hz signal will be observed. In Pass 1, the ramp rate is decreased to -1.0E-06 K/sec and while the chirp is continuously running, T_c will be crossed to T_c-0.02. Pass 1 is expected to take about 2 days

In Pass 2, shear thinning at one frequency and four amplitudes will be measured. The data set will start at 0.02 K below T_c and ramp above T_c to acquire precision viscosity data. The temperature will ramp to as close as T_c+0.003 K, then the ramp rate will be decreased to –2.5E-08 K/sec on the approach to T_c, assuming T_c is known to 0.1mK. Pass 3 will measure shear thinning at four frequencies and four amplitudes. It follows the same process as in Pass 2. Both passes will require a total of about 6 days of continuous operation.

Prior to power down, the cell temperature will then be raised and the battery powered descent heater subsystem will be activated to ensure that the cell does not cool below T_C (~16.7° C) in the time between instrument power down and Shuttle landing. This is estimated to be about 10 hours. *Any wave off (for weather or other reasons) requiring extended time on orbit (and subsequent cool-down of the CVX-2 Experiment Package) would require power up of the experiment to permit use of the primary heaters to maintain the desired sample temperature for landing.*

4.2 EXPERIMENT POWER

The CVX-2 instrument exhibits a stable power draw when the environment is constant. For a constant Earth view, the nominal power required is estimated by analysis to be less than 100 Watts. The environmental control heaters provide the largest demand for power and this increases significantly as the environment becomes cooler. The bounds of these loads are summarized in Table 6.

Table 6: EQUIPMENT POWER PROFILE

PHASE/EQUIPMENT	POWER (watts)			COMMENT/DURATION/ ATTITUDE
	IDLE	NOMINAL	PEAK	
AP Heaters				
Operation (1-200 hr)	0	10	112	Nominal scenario assumes Earth view
EP Heaters				
Operation (1-200 hr)	0	5	75	
AP Electronics				
Operation (1-200 hr)	N/A	75	75	
EP Electronics				
Operation (1-200 hr)	N/A	45	45	Peak scenario assumes deep space (cold) view
Totals				
Operation (1-200 hr)		135	307	

4.3 THERMAL OPERATIONS

The CVX-2 experiment requires careful thermal control at the sample. Both CVX-2 packages are radiative cooled and temperature controlled with surface heaters on the canister lids. This places some constraints on operational limits for Shuttle attitudes with high solar flux (i.e., Bay-to-Sun). It is desirable that the instrument not be interrupted by loss of thermal control because the time to recover control and restart the experiment could result in a major loss of experimental time.

The Bay-to-sun attitude affects measurement and the sample, depending on the duration. These results are based on analysis which has to be verified (both the amount of temperature change and sensitivity of electronics to temperature). The sample is affected by >55 minutes with a 100 lb lid (time is required between following bay-to-sun exposures to cool back down). Violation may require restarting the temperature ramp. This could potentially cause a loss of up to 33 hrs of data.

TABLE 7: THERMAL CONSTRAINTS

THERMOSTATIC EQUIPMENT	DUTY CYCLE (percent by attitude)	POWER (watts)	ATTITUDE/COMMENTS
Lid Heater/EP + thermostat & bridge box	0/21/76	0/20/72	bay to sun/bay to earth/bay to space; 120 W maximum
Heater/AP	0/31/92	0/7/63	ibid.; 112 W maximum

PAYLOAD with *heaters OFF*: (assuming these are *CVX-2 canister heaters*)

*Note: This is NOT a configuration previously analyzed. The instrument is **not** designed to operate without primary environmental controls.*

ATTITUDE	MAXIMUM DURATION	RECOVERY TIME	EFFECT IF VIOLATED
Bay to Sun	~ 55 minutes (limited by EP electronics)	~ 4 hr	Expmt. turned off; loss of expmt. time; restart
Bay to Earth	unlimited (bridge box and other htrs will try to compensate)	N/A	drift in electronics; degradation of data
Bay to Space	~30 minutes	~ 1 hr	Expmt. turned off; loss of expmt. time; restart

PAYLOAD with *heaters ON*:

ATTITUDE	MAXIMUM DURATION	RECOVERY TIME	EFFECT IF VIOLATED
Bay to Sun	55 minutes	~ 4 hr	Expmt. turned off; loss of expmt. time; restart
Bay to Earth	unlimited	N/A	
Bay to Space	unlimited	N/A	

4.4 EXPERIMENT COMMANDING

The CVX-2 instrument will accommodate both autonomous and interactive (commanded) operation. The perfect mission (no measured difference in on-orbit T_c relative to Earth-based measurements, no deviation from timeline, no variation of predicted thermal environment due to Shuttle maneuvers or miscalculation of environmental parameters, and no unexpected deviation in the observed fluid properties to prompt real-time scientific investigation) might require no commanding through CVX-2 CGSE. However, it is expected that commanding will be required to adjust the experiment timeline and to adjust for the fluctuating thermal environment. A limited set of commands will provide the ability to pause and redirect the instrument as the experiment progresses.

The following list of commands has been identified:

pause temperature control (maintain cell temperature)
resume temperature control
reset (reset variables, restart sequence)
set new IVD setpoint
adjust thermostat shell offsets
turn **chirp on/off**
construct new **viscometry sequence**
set new **temperature or ramp rate** in existing sequence
set new **canister temperature** setpoint
initiate low frequency chirp
initiate electronic noise check
sychronize clock to MET
descent heater on/off
retrieve playback data **file**
CVX-2 power on/off (HH command)
CVX-2 Avionics power on/off (HH command)
Run Sequence (this specifies cell signals & amplitude)
Create a custom sequence
Create a custom amplitude

Commands will be reviewed and confirmed by CVX-2 personnel prior to submittal to the HH system for uplink.

4.5 EXPERIMENT TELEMETRY

The flow of data and commands through the CVX-2 instrument is shown in Figure 4. The data stream downlinked (once every 64 seconds) will include:

time stamp
viscometry transfer function (400 points)
cell temperature (32 second average)
thermostat shell **control temperatures** and **heater currents** (eight8 sec. avgs.)

canister **lid temperatures**
canister **middle shelf temperature**
canister **bottom shelf temperatures**
canister **internal pressures**
accelerometry data
all **settable parameters**
AP lid and middle temperatures (via HH avionics)
AP pressure (via HH avionics)
current A (via HH avionics)
current B (via HH avionics)

The most important data is stored on a hard disk drive on orbit as well as downlinked to the POCC. If necessary, selected intervals of stored data may be downlinked to reconstruct or complete the POCC data base; however, to accommodate such transmissions the real time data would not be downlinked (although it will be recorded).

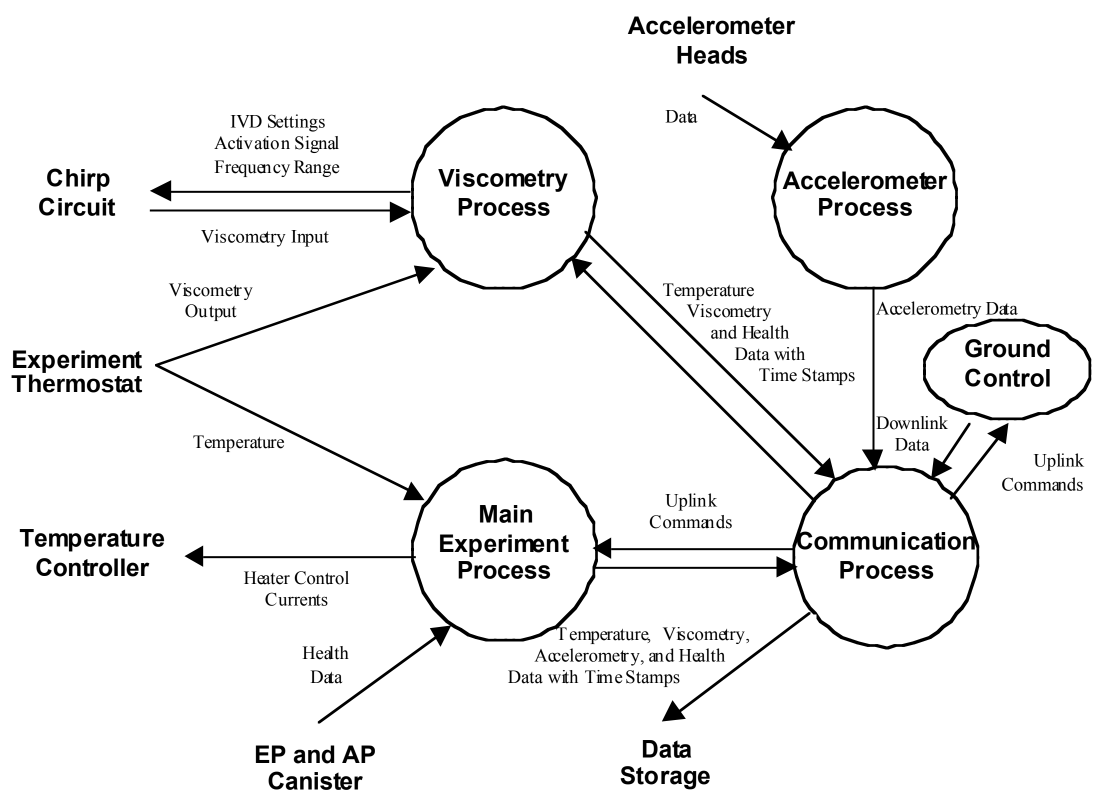


Figure 4: CVX-2 Data Flow Diagram

TABLE 9: LOW RATE DATA STREAM CONTENTS

COMMANDS/TELEMETRY	BAUD	RS232	RS422

OPTION #1*:			
Commanding to CCGSE/ACCESS	1200	yes	no
Async. Data Unformatted	1200	yes	no
OPTION #2*:			
Async. Data Formatted	19.2k	no	no
Analog Data	19.2k	no	no
CCGSE/ACCESS Ancillary Data	19.2k	yes	no
Shuttle Orbit/Attitude Data	19.2k	yes	no
PCM-A	19.2k	no	no
PCM-B	19.2k	no	no
Command Status	19.2k	yes	no
Data Link	19.2k	yes	no
CCGSE/ACCESS AIA Data	19.2k	no	no

* *The choice of options 1 or 2 will be based on additional data from HH*

TABLE 10: MEDIUM RATE DATA CHARACTERISTICS {NOT APPLICABLE}

4.6 CREW INVOLVEMENT

None required.

4.7 ORBITER POINTING

The instrument will be radiatively cooled and, as a result, is affected by the orientation of the orbiter. The sensitivity of the thermal control system to specific orientations has been analyzed and approximate operational constraints are summarized in Table 12. The Bay-to-Sun orientation is the most sensitive for CVX-2, depending on the beta angle.

TABLE 12: ORBITER POINTING RESTRICTIONS
(+Z axis pointing)

Attitude	DURATION	Beta ANGLE	EFFECT IF VIOLATED
RAM	no constraint	no constraint	
Sun	55 minutes	80 degrees	loss of thermal control; loss of run time during recovery
Moon	no constraint	no constraint	
Earth	no constraint	no constraint	
Earthlimb	no constraint	no constraint	
Umbra	no constraint*	no constraint	

* *assuming adequate power is provided*

4.8 INSTRUMENT FIELD OF VIEW

The instrument will be radiatively cooled and *must not* be shaded (especially from top view) and should not view exceptionally warm surfaces if at all possible during operation.

4.9 CONTAMINATION CONSTRAINTS

g-jitter Constraints - The CVX-2 viscometer is a hydro-mechanical device which can be affected by vibrations ("g-jitter") at low frequencies (~0.1 to 10 Hz) and relatively low levels of excitation. The primary approach employed to permit operation through background accelerations is to make multiple measurements while monitoring the local accelerations and (if necessary) discard those measurements perturbed by this interference.

There will be "critical measurement periods" during which extended loss of data would not be acceptable and these will be further documented as the timeline is developed.

Summary of environment:

- DC Accelerations: Affects the sample; if the threshold is violated for >10 sec, the entire ramp would likely have to be restarted.

- AC acceleration: Affects measurement during the period of vibration. Little impact as long as <80% of the frequencies from 0-10 Hz are affected for 45 consecutive minutes out of every 6 hours.
  - Throughout the CVX-2 timeline the threshold is >50 g/rtHz below 10 Hz

We appreciate that these levels are not likely to be explicitly controlled but, based on prior experience and available Shuttle acceleration data, we believe that the requirements ARE achievable during typical missions and we expect to work around obviously active periods of STS and crew operations and will internally monitor acceleration levels. We do request updates on crew exercise schedules and changes in STS thruster activities.

TABLE 13: CONTAMINATION CONSTRAINTS

CONTAMINANT	DURATION OF EXPOSURE	TIME UNTIL OPERATIONS RESUME	EFFECT IF VIOLATED
Payload Bay Lights On	no constraint	N/A	N/A
Flash Evaporator System (FES) Operations	no constraint*	N/A	N/A
Fuel Cell Purge (FCP) Operations	no constraint*	N/A	N/A
Vernier Reaction Control System (VRCS) Burns	no constraint*	N/A	N/A
Primary Reaction Control System (PRCS) Burns	**	time to stabilize orbiter	loss of data; loss of run time
Orbital Maneuvering System (OMS) Burns	**	time to stabilize orbiter	loss of data; loss of run time
Crew Exercise	**	when exercise completed	loss of data; loss of run time
Electron Contamination Regions (ECR)	no constraint	N/A	N/A
Water Dumps	no constraint*	N/A	N/A
South Atlantic Anomaly (SAA)	no constraint	N/A	N/A

** CVX-2 will continue to discuss and evaluate potential impact; current understanding is that CVX-2 can "survive" and/or work around most **typical** Shuttle activities (assuming prior notice is provided).*

** Dependent on point of Tc scan. Close to Tc we are most senstivei, nominally when within 1 mK of Tc.(up to 9.5 hours of scanning).

4.10 CUSTOMER SUPPLIED GROUND SUPPORT EQUIPMENT

CVX-2 will require minimal equipment to support checkout of the instrument after integration (at GSFC and KSC). Plans call for only one external computer (with printer) to support interactive test of instrument function and data links.

TABLE 14: CUSTOMER GROUND SUPPORT EQUIPMENT (CGSE)

TEST SYSTEM *(for GSFC and KSC "on-line" checkout operations)*

CVX-2 equipment:

TYPE/MAKE OF UNIT	WEIGHT	POWER (Voltage/Current)
Personal computers/Pentium (1 ea.)	40 lb.	110 VAC/~2 amp
Laser printer/HP (1 ea.)	25 lb.	110 VAC/~5 amp

Services requested:

Will the CGSE transmit commands?	yes
Will the CGSE receive low rate data?	yes
Will the CGSE receive medium rate data?	no
Number of standard 115 VAC outlets required:	2
Floor space required:	100 sq. ft

OPERATIONAL SYSTEM *(for POCC operations)*

CVX-2 equipment:

TYPE/MAKE OF UNIT	WEIGHT	POWER (Voltage/Current)
Personal computers/Pentium (4 ea.)	40 lb.	110 VAC/~2 amp
Laser printer/HP (1 ea.)	25 lb.	110 VAC/~5 amp
Ink jet printer/TBD (1 ea.)	15 lb.	110 VAC/~1 amp

Services requested:

Number of standard 115 VAC outlets required:	12
Floor space required:	400 sq. ft
Air conditioning required?	yes
Will the CGSE transmit commands?	yes
Will the CGSE receive low rate data?	yes
Will the CGSE receive playback data?	yes
During/Post mission?	during*
Will the CGSE receive medium rate data?	no
Will the CGSE receive orbit/attitude data?	yes*

- *CVX-2 requests additional clarification of HH capabiities at chosen baud rates*

4.11 PAYLOAD OPERATIONS CONTROL CENTER (POCC) REQUIREMENTS

The CVX-2 POCC is envisioned to utilize:

- 4 stations (command, science, engineering, manager)
- 2 additional chairs
- 1 file cabinet (for drawings, documentation, and supplies)
- 1 additional table (work area)
- 1 bookcase (documentation and supplies)

4.12 POST-MISSION DATA PRODUCTS

Do you desire Calibrated Ancillary System (CAS) parameter data? Yes

Do you desire to receive post-mission products of your telemetry data? Yes

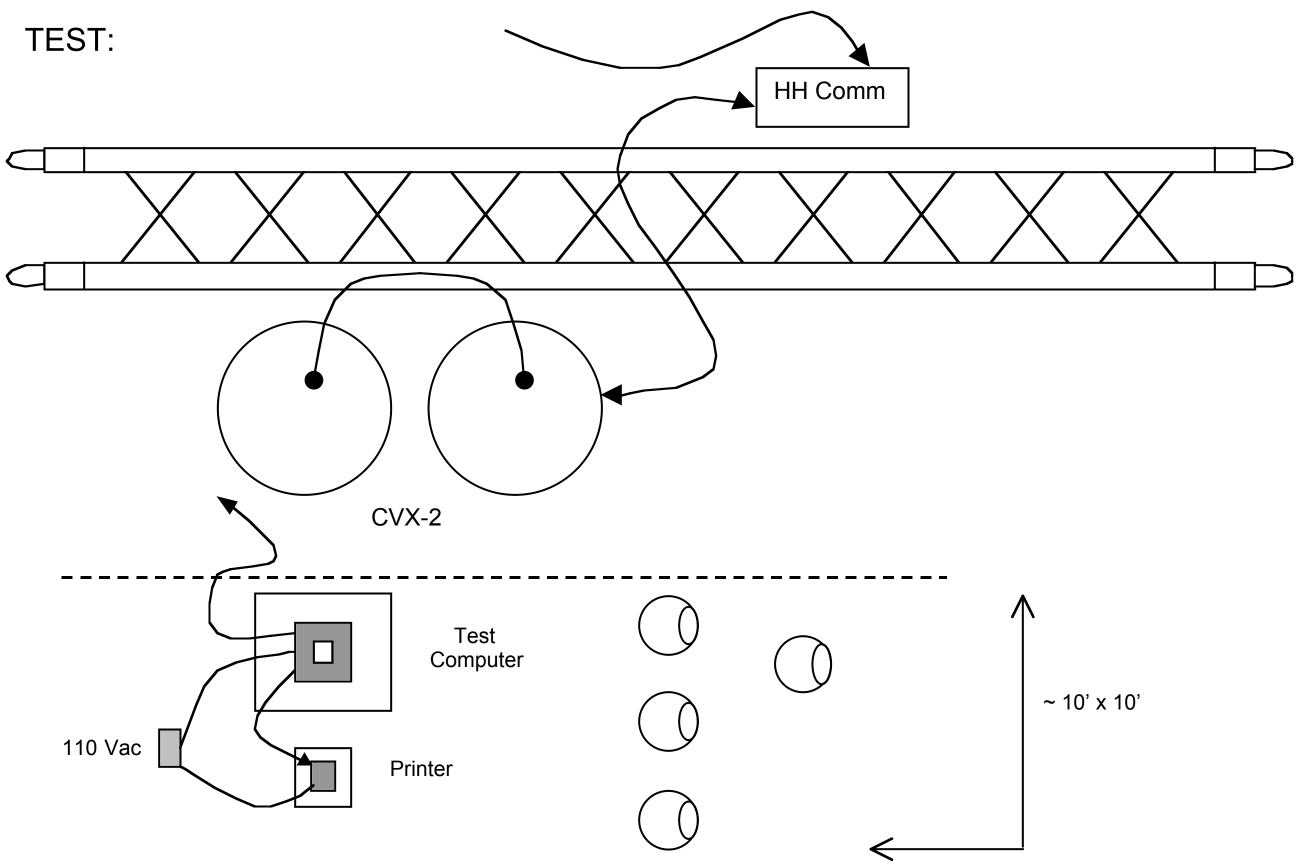
PRODUCT	MEDIUM	TEST TAPE
Low Rate Tim	CD	yes
Medium Rate Tim	N/A	N/A

These products should be sent to:

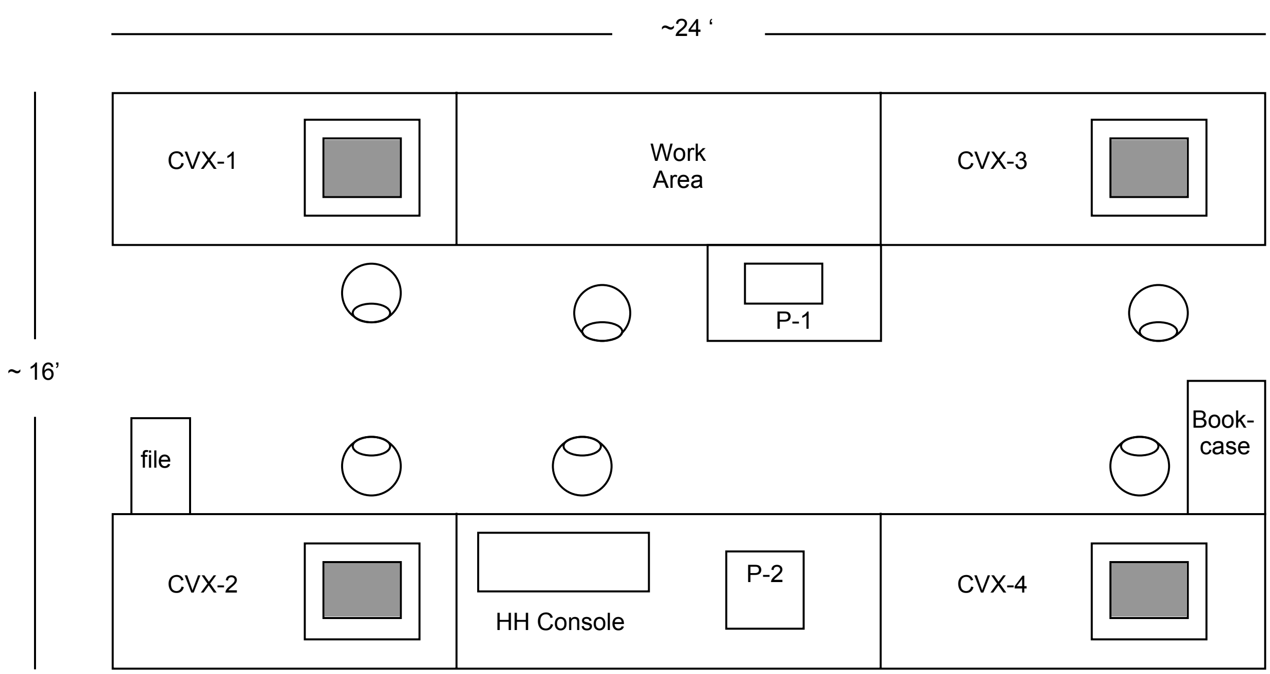
Susan M. Motil
NASA Glenn Research Center
Mail Stop 500-115
21000 Brookpark Road
Cleveland, OH 44135

DIAGRAM 1: CGSE/CCGSE/ACCESS CONFIGURATION

TEST:



OPERATIONS:



5.0 PAYLOAD REQUIREMENTS FOR OPTIONAL SERVICES

a. Custom lids for both canisters
  - CVX-2 will use lids designed for the CVX-1 mission
  - GSFC will support design review and certification as required

b. Custom cable for canister interconnect
  - CVX-2 will design and fabricate to HH specification
  - GSFC will support design review and certification as required

c. Feed-through connectors for lids/cable connectors
  - CVX-2 will procure to HH specification *(same connectors employed by HH)*

d. Application of metallized tape to canister covers and CVX-2 cable for thermal control
  - GSFC will apply to CVX-2 specification *(presumably same as HH)*

e. Standard MLI blankets for thermal control of both canisters
  - GSFC will provide and install to HH specification *(standard HH configuration)*

f. Two shipping containers.

g. Two HH thermistors for instrumenting the AP canister.